SAMPLE RETRIEVAL DEVICE FOR AEROSOL COLLECTION

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of prior filed co-pending U.S. Provisional Application No. 60/434,614, filed on December 19, 2002, the contents of which are incorporated by reference herein.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The present invention generally relates to a sample retrieval device for aerosol collection.

2. Discussion of the Related Art

[0003] Aerosol sampling has become an indispensable process used in a wide range of applications such as, for example, environmental studies, detection of airborne biological or chemical warfare agents, exploration of cosmos, etc. The collection of the impurities, especially in air, can be realized by filtering many particles out of the air. The detection of the collected particles can be performed by, among others, sophisticated diagnosing equipment, e.g., time-of-flight spectrometers.

[0004] Recently, aerosol sample retrieval for chemical analysis by mass spectrometry has developed into an alternative method to on-site monitoring by separating a collection device from an analytical instrumentation. As a consequence, the use of aerosol collecting devices has been diversified and expanded to areas previously considered to be hardly accessible.

[0005] Some of the known collecting devices operate as an impacting type device configured to force entrained particles along a path, which leads the particles to an impactor plate, where these particles are collected upon impact and later analyzed. One of the difficulties in using impactors can be explained by a high kinetic energy possessed by particles entrained in a gas stream. As a consequence, the entrained particles can bounce off the impactor plate and re-entrain the gas stream thereby causing erroneous results during a

subsequent analysis. Another difficulty includes a non-uniform deposit over the entire impaction plate, which is ordinarily mounted stationary mounted relative to a particle guide. However, it is desirable that a deposit be substantially uniform, because it reduces particle re-entrainment.

[0006] To remedy these problems, a "virtual" impactor has been developed to separate particulates from a fluid stream with techniques other than direct impaction. Virtual impactors may operate on a number of different principles, but all avoid actual "impact" as a means to separate particulates from a fluid in which the particulates are entrained. Critically, virtual impactors invariably rely on differences in particulate mass to induce inertial separation.

[0007] Still, the problems associated with actual impactors continue to persist in virtual impactors known for particle "wall loss," i.e., unintended deposition of particulates on various surfaces of virtual impactor structures, especially at curved or bent portions. As a consequence, the virtual impactors are characterized complicated configurations, time-consuming installation and cost inefficient maintenance.

[0008] Thus, many of the known types of the actual and virtual impactors are characterized by a rather expensive and delicate structure difficult to install and maintain.

[0009] It would therefore be desirable to provide a cost-efficient, maintenance-friendly and rugged aerosol collection device, which can be coupled to a vehicle to collect aerosol samples in inaccessible or hazardous environment in a reliable manner.

SUMMARY OF THE INVENTION

[00010] In one embodiment of the present invention, a sample collector is provided and is at least configured to be removably coupled to a vehicle and having multiple intake ports and a rotary collection plate, which are juxtaposed with one another to provide a plurality of concentric tracks of collection spots on the sampling surface to allow for redundancy in the sample collection.

[00011] The sample collector of the present invention has been found to be particularly advantageous when formed from lightweight materials and used with Unmanned Aerial

Vehicles (UAV), e.g., radio controlled electric powered helicopter (RC UAV), which allows for high versatility, maneuverability, and rapid interrogation of otherwise inaccessible and/or hazardous environments. Other advantages of the UAV are its broad commercial availability, relatively cost-efficient and simple structure capable of carrying a payload of up to a pound. As one skilled in the art would readily appreciate, although the following discussion is directed to RC UAV's, the sample collector of the present invention can be associated with any type of vehicle subject only to elementary mechanical modifications of the mounting structure of the device.

[00012] In accordance with another aspect of the present invention, a sample collector is centered along an axis of symmetry and configured so that an air sample, traversing multiple intake ports, is branched among multiple outlet ports positioned asymmetrically relative to the axis of symmetry. The geometry of the intake and outlet ports, each pair of which defines a respective air passage therebetween, can vary subject only to the formation of the multiple tracks of collection points on the rotary plate.

[00013] In accordance with a further aspect of the present invention, the sampling surface is configured as a disk formed with a multiplicity of concentric arrays of ventilation holes. Each array is divided into numerous groups each including several ventilation holes, which surround a respective continuous region of the disk to define a collection point. Hole size affects a filtering capacity of the disk and can vary in accordance with a given task and local requirements.

[00014] It is important to note that the manner in which samples are collected affects the usefulness of the samples for archival purposes. Collected samples are often employed to determine more information about an event occurring at a specific time. For example, archival data collected during a predetermined time and itinerary of flight might be used to determine at what time higher levels of pollution occurred. That time could then be applied to determine at which point of the itinerary such a peak was detected to undertake further necessary measures depending on the determined locale and level of detected pollutants or agents.

[00015] This feature can be addressed in accordance with a further aspect of the present invention by providing a method and device capable of collecting samples for successive sampling periods, and which include time indexing enabling a specific collected sample to be correlated with a specific time at which the sample was taken.

[00016] In accordance with another aspect of the invention, a sample collector is an integral part of a collector/analyzer assembly configured in accordance with thepresent invention. In this manner, not only can the sample collector possess the increased collecting capability, but also it can be readily coupled to a multi-channel time of flight (TOF) mass analyzer to provide for a time-efficient, reliable process.

[00017] The sample collector of the present invention provides for a simple and cost efficient structure configured to provide numerous sample collections and sample identifications while being mounted to a variety of vehicles operating in hazardous environments.

BRIEF DESCRIPTION OF THE DRAWINGS

[00018] The above and other features and advantages will become more readily apparent from the detailed description of the invention accompanied by the following drawings, in which:

[00019] FIG. 1 is a view illustrating the sample retrieval collection device mounted to a radio-controlled unmanned aerial vehicle of the present invention;

[00020] FIG. 2 is an exploded view of the sample retrieval device of the present invention;

[00021] FIG. 3 is an isometric view of the sample retrieval device of the present invention;

[00022] FIG. 4 is a cutaway side view of the sample retrieval device of the present invention; and,

[00023] FIG. 5 is a plan view of a sample disk configured in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[00024] Referring to FIG. 1-4, sample retrieval device 20 is configured to at least perform numerous collections of aerosol samples in remote and hazardous areas reachable by man or remote operated vehicles. Particularly well suited as a carrier for the device 20 is a radio controlled (RC) battery operated helicopter 10 or an RC Unmanned Aerial Vehicle (RC UAV) 10, as illustrated in FIG. 1. Both highly maneuverable and easily assembleable, the RC UAV has a lightweight carbon fiber body including multiple arms 12, each of which has a rotor blade assembly 14 powered by a battery set. A central control module 16 including electronics is mounted on the vehicle's body equidistantly from the rotary blade assemblies 14 and can be configured to carry the device 20, preferably attached to the bottom of the control module. Compared to liquid operated helicopters, the RC UAV is particularly advantageous for collecting air samples, because the latter are not compromised by otherwise contaminating fuels.

[00025] Turning specifically to FIGS. 2-4, the device 20 can be powered by its own power source, with the batteries of the RC UAV 10 being preferred, and is characterized by a housing 50 having any suitable shape, e.g., a polygonal shape or a circular shape. In either case, the device 20 is highly portable and designed, for example, to be about 3" long and wide and about 3" high.

[00026] Housing 50 of device 20 is configured to contain one or more sample plates 52 each optionally having a disk shape, such as, for example, a standard about 3" diameter disk mounted on a base 42 of the device. To reliably mount the disk 52, the base 42 has an aperture 40 dimensioned to fully receive the disk 52, which is thus reliably secured in the housing. Housed in base 42 is a motor 56 (FIG. 4) coupled to and rotating the disk 52 which receives and collects a plurality of air samples during the flight of the helicopter, as will be explained below.

[00027] To prevent interference of device 20 with the aerial maneuverability of the RC UAV 10, housing 50 is configured with air passages 48' and 48" (FIG. 3) located between base 42 and top 22 of housing 50 and extending through the housing to substantially reduce the air resistance of the device during a flight. Formation of air passages 48' and 48" can be

obtained by an air-intake housing part 30 (FIG. 2), juxtaposed with base 42, and lid 24 coupled to the upper portion of the air-intake part 30. In particular, the air-intake part 30 is shaped to have a flat lower portion totally covering the aperture 40 and a recessed upper portion configured to have a pair of side flanges 34 extending from a bottom 36. The lower portion of the lid 24 carries one or more spacers 28 (FIG. 3) supported by bottom 36 and dimensioned to form the air passages 48' and 48", each of which is defined between the spacer(s) and a respective one of the flanges 34. The spacer(s) 28 may be variously shaped and dimensioned and is subject only to the dimensional limitations necessary to provide air passages. Coupling top 22, lid 24, air-intake part 30 and base 42 to one another can be realized by a plurality of fasteners (not shown) preferably extending through the corners of the of device 20.

[00028] To provide flow of air through device 20, base 42 can house a fan 58 (FIG. 4) located under motor 56 and disk 52 and operative to create a negative pressure, which is sufficient to force ambient air through multiple intake ports 30'. The intake ports are provided in cutout regions 32 each formed in a respective one of the flanges 34 of the air-intake part 30 (FIG. 2) of the housing 50. The configuration of the intake ports guides air samples through a plurality of passages 62 leading towards disk 52, which is positioned to be impacted by the air streams and configured to allow numerous collections during a flight.

[00029] The disk(s) 52, rotatable relative to the passages 62, are advantageously fabricated so that two tracks of collections spots 60 and 64 are arranged in concentric inner 66 and outer 68 circular tracks, respectively, as shown in FIG. 5. Arrangement of multiple concentric tracks of collection spots 60, 64 is determined by the configuration of and position of each of the downstream ends or outlets 38 (FIG. 4) of the passages 62 relative to an axis of symmetry S-S (FIG. 4) of the device 20. Forming the downstream ends asymmetrically relative to the axis S-S allows for as many concentric arrays as the number of intake passages, which may be more than two depending on the arrangement of the cutout regions 32. Since the increased volume of the sample is desirable, the outlet ports 38 are dimensioned to be larger than the rest of the passages.

[00030] Preferably, the cutout regions 32 each have a triangular cross-section provided with an apex 18 (FIG. 2), which is located next to a respective intake port 30' (FIGs. 3 and 4), and serve as an airflow trap of air forced into these ports. Since the air passages are formed parallel, the apexes 18 are located asymmetrically to the axis S-S to form two concentric arrays of collections spots as shown in FIG. 2. However the parallel relationship between the passages is not critical; it is the downstream ends of these passages that define a multi-track collection spot arrangement on the disk 52. As a consequence, the cutout regions can be uniform, and the intake ports can be spaced symmetrically from the axis of symmetry S-S, provided that the air passages extend angularly towards one another to have their downstream ends terminate asymmetrically relative to this axis. Alternatively, a micro-porous material (frit or filter) may be used for the collection surface for trapping particulates entrained in the air stream.

[00031] The motor 56 can be, for example, a stepping motor rotatably fixed to the disk 52, which is thus indexed so that any given pair of spaced across the sample disk 52 collection spots 60 and 64 of the inner 66 and outer 68 tracks, respectively, is always aligned with the outlet ports 38. As a consequence, the multiples concentric tracks of collection spots allow for redundancy in the sample, which, in turn, provides for more reliable detection of the collected samples.

[00032] While the sampling surface of the disk 52 is prepared using, for example, activated charcoal, adhesives, or other sample captivating substances, areas surrounding each of the collection spots 60 and 64 each are drilled with an array of vent holes 70 (FIG. 5) traversed by passing air flow. The shape, dimension and quantity of the vent holes can be selected to address the local requirements. To evacuate the air from the housing 50, base 42 (FIG. 3) is provided with numerous recesses 72 providing flow communications between the interior of the housing and the atmosphere.

[00033] Following the collection cycle, helicopter 10 is recovered, the sample disk 52 is removed, and subsequently loaded into a multi-channel time of flight (TOF) mass analyzer 75 (FIG. 5), e.g., a multi-channel time of flight (TOF) mass analyzer as disclosed in U.S. Patent No. 6,580,070 to Cornish et al., the contents of which are incorporated by reference

herein. The multiple tracks are indexed through the multiple mass spectrometer channels allowing for a rapid and redundant assessment of the environmental aerosol sample.

[00034] It will be understood that various modifications may be made to the embodiments disclosed herein. Therefore, the above description should not be construed as limiting the scope of the invention, but merely as exemplifications of the preferred embodiments. Those skilled in the art will envision other modifications within the scope and spirit of the claims appended hereto.